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Alaska Department of Fish and Game
Commercial Fisheries Management
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P.O. Box 25526
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Abundance, Age, Sex and Size Statistics for Pacific Herring in Lower Cook Inlet, 1991

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The Technical Fishery Report Series was established in 1987, replacing the Technical Data Report Series. The scope of this new series has been broadened to include reports that may contain data analysis, although data oriented reports lacking substantial analysis will continue to be included. The new series maintains an emphasis on timely reporting of recently gathered information, and this may sometimes require use of data subject to minor future adjustments. Reports published in this series are generally interim, annual, or iterative rather than final reports summarizing a completed study or project. They are technically oriented and intended for use primarily by fishery professionals and technically oriented fishing industry representatives. Publications in this series have received several editorial reviews and at least one *blind* peer review refereed by the division's editor and have been determined to be consistent with the division's publication policies and standards.

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ABSTRACT

The 1991 spawning biomass of Pacific herring *Clupea pallasi* in the Kamishak Bay District of the Lower Cook Inlet Management Area in Alaska was estimated to be 14,648 tonnes (16,147 tons) from a modified preseason forecast. The district was open to commercial purse seining on 26 April when 1,807.3 tonnes (1,992.2 tons) of sac roe herring were harvested. Herring were observed as late as 12 June in the Kamishak Bay District, but the late-spawning herring were not sampled for age composition. Early-spawning herring in the Kamishak District were sampled for sex, age, weight, and length. There were more males (52.7%) than females, and age-7 herring from the 1984 year class represented 40.4% of the sample. Age-3 herring were 9.9% of the samples. Mean weight and length of both sexes combined were 201 g and 236 mm. Age composition of the composite spawning population were estimated from the regression of composite age composition on early age composition. The composite age-3 proportion was estimated to be 35.5%.

The spawning biomass in the Southern District was estimated to be 901.3 tonnes (993.5 tons) from aerial surveys. This district was not opened to commercial fishing. No age composition samples were collected.

There were no biomass estimates for the Outer and Eastern Districts. Although the Outer and Eastern Districts were open to commercial purse seining between 10 and 31 May, no harvest occurred. A limited age composition sample (n = 98) was 94.9% age 3.

KEY WORDS: Abundance, age, *Clupea pallasi*, Pacific herring, length, Lower Cook Inlet, sex, weight

INTRODUCTION

The Lower Cook Inlet Management Area consists of waters under state jurisdiction west of Cape Fairfield in the Gulf of Alaska, north of Cape Douglas in Shelikof Straits, and south of Anchor Point in Cook Inlet. This management area is subdivided into four management districts: Kamishak, Southern, Outer, and Eastern (Figure 1). Commercial fishing for Pacific herring *Clupea pallasi* in Lower Cook Inlet is presently limited to a sac roe fishery concentrated in the Kamishak Bay District. By regulation, purse seines have been the only gear allowed. Entry into the sac roe fishery was limited in 1978 when 75 permits were issued. Currently, all of the Lower Cook Inlet sac roe harvest is from Kamishak Bay where roe recovery rates are higher because the fish are older. Although the abundance of herring in the Eastern District at this time is high, they rarely exceed age 4. The Kamishak Bay District run biomass had fallen to a low of 1,093 tonnes (1,202 tons) in 1978 but rebounded to a peak of 32,120 tonnes (35,332 tons) in 1987. The 1990 run biomass was estimated to be 19,623 tonnes (17,847 tons) and two year classes 1983 and 1984, accounted for 66% of that biomass.

Fishing for herring in Lower Cook Inlet began in 1914 as a gillnet fishery for salteries in the Southern District (Kachemak Bay). Purse seines were introduced in 1923. This fishery grew to a peak between 1924 and 1926 before collapsing. A purse seine fishery for oil and meal reduction began in 1939 in Resurrection Bay in the Eastern District. Harvest levels peaked between 1944 and 1946 before the fishery collapsed during the late 1950s. Commercial sac roe fishing with purse seines started in 1969 in the Eastern and Southern Districts and 1973 in the Kamishak District. The sac roe fishery also collapsed in 1980 and all districts were closed to commercial fishing. The Kamishak, Eastern, and Outer Districts were reopened in 1985. The Eastern and Outer Districts were closed again during 1990. The Southern District was reopened to fishing only during 1989. A complete history of commercial fishing for herring in Lower Cook Inlet can be found in Schroeder (1989).

Documentation of herring catches in Lower Cook Inlet by the Alaska Department of Fish and Game (ADF&G) began in 1961. Sampling of the catch for age, sex, weight, and length (AWL) data began in 1971. Assessment of the spawning biomass began in 1978 with a program of aerial surveys and test fishing for age composition. The annual summaries of catch and run biomass can be found in the Lower Cook Inlet Annual Management Reports (Bucher and Hammarstrom 1993). The 1971–1987 AWL data was summarized by Schroeder (1989). Sampling data after 1987 has been reported annually by Yuen et al. (1989, 1990, 1991).

ADF&G uses age composition and aerial surveys to prepare its annual herring stock assessment, and in 1991 Southern District run biomass was estimated in this way. However, bad weather reduced the number of aerial surveys of the Kamishak Bay District during 1991 and precluded a conventional aerial survey biomass estimate. Therefore, the Kamishak run biomass was estimated from a modified preseason forecast model and an aerial survey run time 'expansion' model. Kamishak and Outer District age compositions were estimated from catch and test fishing samples, respectively.

METHODS

Biomass Estimates

Run biomass refers to the spawning segment of the herring population on the fishing grounds between mid-April and June. These herring are considered recruited into the fishery and available to the sac roe fishing fleet, although harvest limits are typically achieved by mid-May. Escapement biomass, or portion of the run biomass that was not harvested, was obtained by subtracting the harvest from the run biomass. The harvest was obtained directly from harvest receipts, or *fish tickets*, which document each sale by a licensed fisher.

Aerial surveys of biomass were flown in a single engine aircraft as close to an altitude of 457 m (1,500 ft) as possible. Although flown at various tide stages, surveys during the 3 to 4 h period following low slack tide appeared to report the best water clarity and visibility of herring schools. Numbers and distribution of herring schools, location and extent of milt, and visibility factors affecting survey conditions were recorded in index maps for each survey. Standard conversion factors were used to convert herring school surface area to biomass: 1.38 tonnes/7 m^2 (1.52 tons/538 ft^2) for water depths <4.9 m (16 ft), 2.33 tonnes/7 m^2 (2.56 tons/538 ft^2) for depths between 4.9 m and 7.9 m (16 and 26 ft), and 2.57 tonnes/7 m^2 (2.83 tons/538 ft^2) for depths >7.9 m (26 ft). Aerial survey estimates were not calibrated in 1991.

Schooling behavior in the Kamishak Bay and Southern Districts were different and consequently aerial surveys from each district were treated differently. Herring in the Kamishak Bay District appeared to be moving in all areas and periods during 1991. Therefore each day's observed biomass was accumulated to create a run biomass estimate. If more than one survey was flown per day in the Kamishak Bay District, the larger survey was used as the biomass estimate. The opposite was observed in the Southern District in 1991, where herring appeared to remain in a given area over several days. In a situation like this, the peak survey over a 7-d period was used as the biomass estimate. However, no peaks were observed this year, and the sum of all surveys was used as the estimate of run biomass instead.

Because inclement weather obscured visibility for the surveyors in the Kamishak District, two alternate methods were used to estimate the 1991 Kamishak run biomass: (1) a modified preseason forecast of the 1991 run biomass based on the 1990 escapement biomass and (2) an expansion of the aerial surveys that were flown (Yuen *in press a*).

The preseason forecast model and data (Yuen et al 1990) were modified. First, we updated estimates of age-specific *(i)* instantaneous natural mortality M_i and recruitment R_i to take advantage of a newly edited age-weight-length (AWL) data base (Yuen *in press b*). Next, we used a moving average of M_i+R_i (recent half of data set) smoothed across adjacent ages. Last, we converted abundance to biomass using the observed 1991 mean weight-at-age statistics. In the original preseason forecast, the moving average of M_i+R_i was not smoothed across ages, except M_6+R_6, and the preseason abundance was converted to biomass using a predicted mean weight-at-age.

The aerial survey expansion divides the daily aerial survey estimate of biomass, b_d, by the proportion of run biomass, p_d, expected on date d to obtain a daily estimate of run biomass B_d. The average of each daily estimate was used as the run biomass estimate

$$\bar{B}_{1991} = \frac{\sum_{d=1}^{D} \frac{b_d}{\bar{p}_d}}{D} \tag{1}$$

where D = number of days when aerial surveyors observed herring and p is greater than zero (Yuen *in press a*).

Age, Weight, Length, and Sex Compositions

In the Kamishak District there were two sampling strata during 1991: catch samples and test fishing samples. Catch samples were obtained during the single fishery opening from haphazardly selected fishing vessels. Fishing was limited to the area around Chenik so there were neither temporal nor geographical distances between sampled vessels in 1991. The sampled fishing vessels were waiting for a tender to pump their fish out of their pursed seines when samples were dip-netted from the seine net. Test fishing samples from the Kamishak Bay District were obtained either from a trawl catch conducted by ADF&G or from commercial purse seiners who agreed to fish at a specified time and area as directed by ADF&G. In the Outer District only one test fishing sample was provided by a fisher.

Sample sizes, n, were set for the catch samples such that all of the estimated age class (i) proportions, p_i, from a multinomial distribution of k age groups were simultaneously within a specified distance, d, of their true population age proportions, π_i, 95% of the time (1 - α). That is,

$$P\{\bigcap_{i=1}^{k} |p_i - \pi_i| \leq d\} \geq 1 - \alpha, \tag{2}$$

where d and α, the confidence level, were chosen to be 0.05 and P was the probability of the hypothesis. Thompson (1987) calculated a maximum sample size of 510 for a worst-case scenario when three age classes were present in equal numbers and $d = \alpha = 0.05$. Any deviation in the number of age classes or unequal contributions by age class would result in a smaller sample size needed to achieve the same level of precision.

The samples were processed immediately to produce a timely age composition summary for the fishery managers. Although the number of fish collected was 510, plus a 30% allowance for unageable scales,

not all of the collection was sampled. Instead, the minimum sample size was equal to the value of n that satisfied

$$\sum_{i=3}^{16} 2\left[1-\Phi\left(\frac{d\sqrt{n}}{\sqrt{(p_i(1-p_i))}}\right)\right]<0.05, \tag{3}$$

where p_i was the *a priori* age proportions obtained when about two-thirds of the collection (300 fish) was aged and the function Φ was the area under the standard normal distribution. After the ages of n fish were obtained, equation (2) was recalculated. If the *a priori* estimate of sample size was found to be insufficient, additional fish were processed.

The samples were packaged in 15-kg (33-lb) boxes and flown to Homer for processing. If there were more fish than was required for a sampling stratum, each 15-kg box was subsampled by dumping the same proportion from all of the 15-kg boxes into a sink and processing every fish in the sink. This was repeated as necessary.

Sex was determined from inspection of gonads or sex products. Each fish was measured to the nearest mm from the tip of the snout to the end of the hyperal plate and weighed to the nearest g. Estimates of standard error for lengths and weights by age class were derived according to the procedures for stratified random sampling described by Snedecor and Cochran (1967); i.e.,

$$SE=\sqrt{\sum(\frac{C_h}{C})^2(\frac{s_h^2}{n_h})}, \tag{4}$$

where C = the herring catch, h = stratum or sample, s_h^2 = sample variance, and n_h = sample size.

The scales of up to 20 fish were mounted on a glass slide. One scale was removed, preferably, from the left side of the herring above the pectoral fin, 3 or 4 scales posterior of the operculum. If scales above the pectoral fin were not present on the left side, they were collected from the same area on the right side of the fish. If that was not possible, then the specimen was not used in the sample. The scales were cleaned, dipped in a 10% mucilage solution and positioned unsculptured side down on a labeled glass slide. Scale images were magnified 29x by a microfiche reader and the number of annuli per scale were counted to determine age.

The abundance of age-4 herring observed during 1992 suggest a large recruitment of age-3 herring during 1991. Historically, Kamishak age composition samples have shown either an influx of age-4 and older herring in late-April and greater numbers of age-3 and older herring mid-May. However, no age composition data were obtained after the commercial fishery in 1991 because of budget constraints.

Instead, we predicted a composite age composition from the early age compositions from the following regression model (Yuen *in press b*) to compensate for the foregone late age composition samples:

$$p_{i,composite} = e^{2.244187 - 1.96111 \ln(age_i) + 0.535726 \ln(p_{i,early})}. \quad (5)$$

RESULTS

Kamishak Bay District

Run Biomass Estimate

Eighteen aerial surveys were flown between 21 April and 12 June in the Kamishak Bay District (Table 1). Herring were observed in seven surveys but not in four. Survey conditions were poor or unsatisfactory (visibility obscured due to weather) in the remaining seven. Distinct spawning migrations could not be delineated because there were 20 consecutive days of missing data. Kamishak Bay District herring typically appear earlier in the south (Chenik, Nordyke, and Kamishak) than in the north (Oil and Dry Bay), and that may have occurred during 1991.

The original preseason run biomass forecast for 1991 was 15,687 tonnes (17,256 tons). The modified preseason run biomass forecast of 14,679 tonnes (16,147 tons) was selected as the final estimate (Table 2), and the expanded aerial survey estimate of 7,115 tonnes (7,826 tons) was rejected because it did not reconcile with the 1992 observed biomass, even with optimistic survival and recruitment rates. Furthermore, the 21,888-tonne (24,077-ton) run biomass reported for 1992 was considered a conservative estimate because there were 17 consecutive days of missing data between April and May (Bucher and Hammerstrom 1992).

When we edited the historical AWL database, we found unexpected decreases in the annual abundance in 1983, 1985, and 1990 (Figure 2). Data from these years were not used to calculate the revised $M+R$ schedules. The following estimates of $M+R$ were also not used because their sign was opposite to at least 6 of their 8 neighbors: $M_{15}+R_{15}$ for year class 1973, $M_{10}+R_{10}$ for year class 1978, and M_4+R_4 for year class 1974 (Figure 3). The smoothed moving average of the remaining data is presented in Figure 4.

The preseason harvest projection was 1,412 tonnes (1,553 tons; Funk 1991). The district was opened to commercial fishing on 26 April with 58 permit holders participating. The actual harvest was estimated to be 1,807.3 tonnes (1,992.2 tons). The difference between the run biomass and the harvest biomass, 12,840.7 tonnes (14,154.8 tons), was the escapement biomass.

Age Composition

Several catch samples were collected in Chenik on 26 April. We compared them with a chi-square test of independence and found them to be similar. The samples were lumped into a single sample of 1,010 readable scales and used to describe the entire harvest (Table 3). This sample was considered from the early-spawning herring because the age compositions were close to the forecasted age composition (i.e., 40% less than age 7 and 49% ages 7 and 8) and had a bias toward the older age groups (i.e., 34.5% less than age 7 and 54.3% ages 7 and 8).

Two samples were collected from a trawl and purse seine prior to the fishery in Iniskin Bay on 23 April. The trawl samples were 93.6% age-1 prerecruits, and the purse seine sample differed from the catch sample in the proportion of age groups 7 and 8. The differences were statistically significant and could not be ignored as those two age groups comprised 55% of the Chenik samples. This sample (Table 4) was not used to describe any segment of the run biomass because of their small sample sizes. The 1991 composite age composition predicted from the early-spawning herring age composition using equation (5) is presented in Table 5 and Figure 5. Updated annual age composition, mean weight, and mean length by year class and age are presented in Appendices A-C.

Southern District Run Biomass

The preseason forecast was for a run biomass of 5,649.1 tonnes (6,214.0 tons; Funk 1991). However, aerial surveyors estimated the run biomass in the Southern District between 30 April and 24 May to be only 901.3 tonnes (993.5 tons; Table 6). This district was not opened to commercial fishing. No age composition samples were collected.

Outer and Eastern District Age Composition

The Outer and Eastern Districts were opened to commercial purse seining between 10 and 31 May but no harvest occurred. A small sample (n = 98) was obtained in the Outer District from test fishing. Most of the sample were age 3 (Table 7). No biomass estimates were made for the Outer and Eastern Districts.

DISCUSSION

Recent budget cuts have eliminated sampling the late migration for age composition and aerial survey calibrations. Bad weather can limit the number of aerial surveys making aerial biomass estimates suspect. Therefore, Yuen (*in press a*) tried to predict run biomass from a set of aerial surveys; Yuen (*in press b*) also tried to estimate composite age composition from the early age composition. Both methods have restrictions that must be met before a reasonable prediction can be made. When estimating run biomass,

at least eight qualifying aerial surveys are required to avoid double-digit prediction errors. For an aerial survey to qualify, herring must have been observed and the expected proportion of the run biomass on the date when herring were seen must be greater than zero. There were only seven qualifying surveys in 1991. When estimating the composite age composition, we had to know the following-year age composition to select one of three competing scenarios for the 1991 age composition: (1) no influx of younger-aged herring in the late migration, (2) an increase in age-4 and older herring during late April, or (3) an influx of age-3 and older herring during mid-May.

The 1991 abundance-age composition report and the 1992 Kamishak preseason forecast were prepared out of sequence because of a deadline for the 1993 forecast. Furthermore, two new estimates of run biomass (Yuen *in press a*) and composite age compositions (Yuen *in press b*) were not completed until after the 1993 preseason forecast was made. The consequences were (1) the run biomass estimate of 16,877 tonnes (18,565 tons) used for the 1992 forecast does not match the run biomass estimate in this report, and (2) the 1992 forecast was prepared as if scenario 1 occurred, i.e. no influx of younger-aged herring in the late migration (Funk and Harris 1992; Yuen and Bucher 1992). The 1992 age composition, however, had a large proportion age-4 herring suggesting that scenario 2, i.e. an increase in age-4 and older herring during late April, occurred instead during 1991.

LITERATURE CITED

Bucher, W.A., and L. Hammarstrom. 1993. 1991 Lower Cook Inlet area annual finfish management report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A93-10, Anchorage.

Bucher, W.A., and L.F. Hammarstrom. 1992. Review of the 1992 Lower Cook Inlet commercial herring fishery. Report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A92-15, Anchorage.

Funk, F., 1991. Preliminary forecasts of catch and stock abundance for 1991 Alaska herring fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J91-03, Juneau.

Funk, F., and M. Harris. 1992. Preliminary forecasts of catch and stock abundance for 1992 Alaska herring fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J92-04, Juneau.

Schroeder, T.R. 1989. A summary of historical data for the Lower Cook Inlet, Alaska, Pacific herring sac roe fishery. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fisheries Research Bulletin 89-04, Juneau.

LITERATURE CITED (Continued)

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods, 6th edition. John Wiley and Sons, New York, New York.

Thompson, S.K. 1987. Sample sizes for estimating multinomial proportions. The American Statistician 41:42-46.

Yuen, H.J. *In press (a).* Herring run biomass estimates from expansion of aerial surveys and run timing in Lower Cook Inlet. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin, Juneau.

Yuen, H.J. *In press (b).* Age composition of early and late spawning migrations of Pacific herring in Lower Cook Inlet. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin, Juneau.

Yuen, H.J., and W.A. Bucher 1992. Lower Cook Inlet herring forecast for 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A92-10, Anchorage.

Yuen, H.J., W.A. Bucher, and W.R. Bechtol. 1991. Abundance, age, sex, and size statistics for Pacific herring in Lower Cook Inlet, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 91-10, Juneau.

Yuen, H.J., W.A. Bucher, and R. Morrison. 1990. Methods of the 1991 Kamishak herring stock projection. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2H90-16, Anchorage.

Yuen, H.J., T.R. Schroeder, and R. Morrison. 1989. Abundance, age, sex, and size composition for Pacific herring in Lower Cook Inlet, 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 89-10, Juneau.

Yuen, H.J., T.R. Schroeder, and R. Morrison. 1990. Abundance, age, sex, and size statistics for Pacific herring in Lower Cook Inlet, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 90-10, Juneau.

Table 1. Herring biomass estimates by area and date[a], Kamishak Bay District, 1991.

Biomass Estimates in Tonnes

date	Survey Conditions	Dry Bay	Oil Bay	Iniskin Bay	Cottonwood Bay	Ursus Cove	Fort. Bluff	Bruin Amakd.	Chenik Nordyke	Kamishak	Douglas Reef	Augustine Island	Total
4 21	fair			0		0	0	0	0	0	0		0
4 23	good	0	0	0	0	0	0	0	0	0	0	0	0
4 24	fair			0	0	0	0	0	516	215	0		732
4 26	fair			0	0	0	0	0	0	0	0		0
4 27	poor												?
4 28	poor												?
5 1	poor												?
5 3	poor												?
5 6	poor												?
5 7	poor												?
5 8	unsatisfactory												?
5 15	good	0	0	470	0	51	11	369	5	0	0		906
5 16	fair	0	0	326	0	74	15	25	0	0	0		440
5 19	fair	0	0	97	0	0	0	7	0	0	0		105
5 22	good	0	108	456	3	305	61	100	0	0	0		1,033
5 24	excellent	0	0	0	0	0	0	0	0	0	0		0
5 31	good	3	0	0	0	112	0	0	0	0	0		115
6 12	fair	2	0	0	0	0	0	0	0				2
Total		5	108	1,350	3	541	87	501	522	215	0	0	3,332

Biomass Estimates in Tons

date	Survey Conditions	Dry Bay	Oil Bay	Iniskin Bay	Cottonwood Bay	Ursus Cove	Fort. Bluff	Bruin Amakd.	Chenik Nordyke	Kamishak	Douglas Reef	Augustine Island	Total
4 21	fair			0		0	0	0	0	0	0		0
4 23	good	0	0	0	0	0	0	0	0	0	0	0	0
4 24	fair			0	0	0	0	0	568	237	0		805
4 26	fair			0	0	0	0	0	0	0	0		0
4 27	poor												?
4 28	poor												?
5 1	poor												?
5 3	poor												?
5 6	poor												?
5 7	poor												?
5 8	unsatisfactory												?
5 15	good	0	0	517	0	56	12	406	6	0	0		997
5 16	fair	0	0	359	0	81	17	27	0	0	0		484
5 19	fair	0	0	107	0	0	0	8	0	0	0		115
5 22	good	0	119	502	3	335	67	110	0	0	0		1,136
5 24	excellent	0	0	0	0	0	0	0	0	0	0		0
5 31	good	3	0	0	0	123	0	0	0	0	0		126
6 12	fair	2	0	0	0	0	0	0	0				2
Total		5	119	1,485	3	595	96	551	574	237	0	0	3,665

[a] If more than one survey per day, the survey with the larger estimate or better survey rating was used.

Table 2. Final estimate of the 1991 Kamishak herring run biomass derived from a modified preseason forecast.

Age	1990 Escapement (No. Fish x 1,000)	Revised Instantaneous Mortality & Recruitment Schedule	1991 Forecast (No. Fish x 1,000)	1991 Predicted Composite Age Composition	Adjust Forecast No. Fish (x 1,000) to Match Predicted Age	1991 Actual Mean Wt (g)	1991 Modified Preseason Biomass Forecast (tonnes)	1991 Modified Preseason Biomass Forecast (tons)	1991 Actual Harvest (No. Fish x 1,000)	1991 Estimated Escapement (No. Fish x 1,000)
2	6	-1.60								
3	5,046	-1.12	30	0.355	34,689	77	2,671	2,944	889	33,800
4	10,391	-0.51	15,465	0.165	16,123	119	1,919	2,115	613	15,510
5	7,262	-0.20	17,304	0.117	11,433	171	1,955	2,155	729	10,704
6	24,794	-0.10	8,870	0.090	8,795	198	1,741	1,919	871	7,924
7	20,345	0.06	27,402	0.143	13,974	211	2,948	3,250	3627	10,347
8	3,791	0.29	19,160	0.065	6,352	258	1,639	1,806	1333	5,019
9	5,663	0.47	2,837	0.020	1,954	269	526	579	231	1,723
10	3,712	0.70	3,539	0.021	2,052	278	570	629	382	1,670
11	1,683	0.89	1,843	0.011	1,075	298	320	353	151	924
12	783	0.91	691	0.006	586	298	175	193	80	506
13	478	0.95	315	0.004	391	314	123	135	53	338
14	186	0.90	185	0.002	195	313	61	67	18	177
15	114	1.00	76							
Total	84,248		97,717	0.999	97,619		14,648	16,147	8,977	88,642
Mean						201				

Table 3. Age, sex, and size composition of herring sac roe harvest, Chenik, 26 April 1991.

		Numbers of Fish						Percent	Weight			Length			Biomass		
	Age	Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total	of Total	Mean (g)	SD	Number Weighed	Mean (mm)	SD	Number Measured	No. Fish X 1000	Tons	Tonnes
	1																
	2																
	3	66	6	27	1	0	100	9.9	77	10.7	100	181	7.7	100	889	75.9	68.9
	4	41	2	26	0	0	69	6.8	119	14.3	69	207	8.5	69	613	80.3	72.8
	5	38	0	43	0	1	82	8.1	171	22.3	82	229	9.7	82	729	137.5	124.8
	6	53	0	44	1	0	98	9.7	198	25.6	98	238	9.1	98	871	190.6	172.9
	7	208	0	198	2	0	408	40.4	211	28.0	408	241	10.3	408	3627	843.0	764.8
26 April	8	65	1	83	1	0	150	14.9	258	35.2	150	256	10.4	150	1333	378.8	343.7
	9	16	0	10	0	0	26	2.6	269	28.7	26	262	9.3	26	231	68.5	62.2
	10	27	1	15	0	0	43	4.3	278	36.0	43	261	8.9	43	382	117.0	106.2
	11	8	0	9	0	0	17	1.7	298	45.7	17	267	11.8	17	151	49.6	45.0
	12	6	0	3	0	0	9	0.9	298	50.6	9	270	12.6	9	80	26.3	23.9
	13	2	0	4	0	0	6	0.6	314	57.1	6	272	12.7	6	53	18.5	16.7
	14	2	0	0	0	0	2	0.2	313	15.6	2	269	2.1	2	18	6.1	5.6
	15																
	16																
Sample Total		532	10	462	5	1	1010	100.0	201	63.6	1010	236	24.4	1010	8979	1992.2	1807.3
Sex Composition		52.7	1.0	45.7	.5												
Unaged		31	0	39	1	0	71	7.0	229	54.0	71	245	18.9	71			
Sex Composition		43.7	.0	54.9	1.4												

Table 4. Age, sex, and size composition of 23 April Iniskin Bay test fish samples, 1990.

		Numbers of Fish						Percent	Weight			Length			Biomass		
	Age	Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total	of Total	Mean (g)	SD	Number Weighed	Mean (mm)	SD	Number Measured	No. Fish X 1000	Tons	Tonnes
Trawl	1	0	0	0	0	131	131	93.6	4	1.8	130	70	10.5	131			
	2																
	3	1	0	0	0	0	1	0.7	0	0.0	0	190	0.0	1			
	4																
	5																
	6	0	0	1	0	0	1	0.7	0	0.0	0	243	0.0	1			
	7	1	0	1	0	0	2	1.4	0	0.0	0	262	1.4	2			
	8																
	9	1	0	1	0	0	2	1.4	0	0.0	0	259	4.9	2			
	10	1	0	1	0	0	2	1.4	0	0.0	0	265	0.7	2			
	11																
	12	1	0	0	0	0	1	0.7	0	0.0	0	256	0.0	1			
	13																
	14																
	15																
Sample Total		5	0	4	0	131	140	100.0	4	1.8	130	81	46.1	140			
Purse Seine	1																
	2																
	3	1	0	0	0	0	1	1.6	81	0.0	1	189	0.0	1			
	4	5	0	0	0	0	5	7.9	124	13.4	5	214	7.3	5			
	5	3	0	1	0	0	4	6.3	151	20.5	4	222	7.6	4			
	6	2	0	3	0	0	5	7.9	208	33.1	5	242	10.4	5			
	7	5	0	6	0	0	11	17.5	215	40.5	11	243	10.8	11			
	8	12	0	13	0	0	25	39.7	263	28.1	25	255	7.2	25			
	9	1	0	0	0	0	1	1.6	222	0.0	1	245	0.0	1			
	10	0	0	3	0	0	3	4.8	301	22.9	3	272	12.5	3			
	11	1	0	2	0	0	3	4.8	283	20.2	3	265	6.8	3			
	12	0	0	3	0	0	3	4.8	354	31.3	3	276	8.9	3			
	13	1	0	1	0	0	2	3.2	311	75.7	2	266	15.6	2			
	14																
	15																
Sample Total		31	0	32	0	0	63	100.0	237	65.4	63	248	19.4	63			

-continued-

Table 4. (page 2 of 2)

		Numbers of Fish						Percent	Weight			Length			Biomass		
	Age	Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total	of Total	Mean (g)	SD	Number Weighed	Mean (mm)	SD	Number Measured	No. Fish X 1000	Tons	Tonnes
	1	0	0	0	0	131	131	64.5	4	1.8	130	70	10.5	131	8	0.0	0.0
	2																
	3	2	0	0	0	0	2	1.0	81	0.0	1	190	0.7	2	0	0.0	0.0
	4	5	0	0	0	0	5	2.5	124	13.4	5	214	7.3	5	0	0.0	0.0
	5	3	0	1	0	0	4	2.0	151	20.5	4	222	7.6	4	0	0.0	0.0
	6	2	0	4	0	0	6	3.0	208	33.1	5	242	9.3	6	0	0.1	0.1
Trawl and	7	6	0	7	0	0	13	6.4	215	40.5	11	246	12.3	13	1	0.2	0.1
Purse Seine	8	12	0	13	0	0	25	12.3	263	28.1	25	255	7.2	25	1	0.4	0.4
Combined	9	2	0	1	0	0	3	1.5	222	0.0	1	254	8.5	3	0	0.0	0.0
	10	1	0	4	0	0	5	2.5	301	22.9	3	269	9.8	5	0	0.1	0.1
	11	1	0	2	0	0	3	1.5	283	20.2	3	265	6.8	3	0	0.1	0.1
	12	1	0	3	0	0	4	2.0	354	31.3	3	271	12.4	4	0	0.1	0.1
	13	1	0	1	0	0	2	1.0	311	75.7	2	266	15.6	2	0	0.0	0.0
	14																
	15																
	16																
Combined Total		36	0	36	0	131	203	100.0	80	115.9	193	133	86.8	203	11	1.0	0.9
Sex Composition		17.7	.0	17.7	.0												
Unaged		0	0	1	0	0	1	.5	329	.0	1	270	.0	1			
Sex Composition		.0	.0	100.0	.0												

Table 5. Composite age composition predicted from early age composition.

Age	Late-April Age Composition	Initial Predicted Composite Age Composition	Standardized Predicted Composite Age Composition
3	0.099	0.317	0.355
4	0.068	0.147	0.165
5	0.081	0.105	0.117
6	0.097	0.080	0.090
7	0.404	0.128	0.143
8	0.149	0.058	0.065
9	0.026	0.018	0.020
10	0.043	0.019	0.021
11	0.017	0.010	0.011
12	0.009	0.006	0.006
13	0.006	0.004	0.004
14	0.002	0.002	0.002
Total		0.893	1.000

Table 6. Herring biomass estimates by area and date, Southern District, 1990.

Biomass Estimates in Tonnes

date	Survey Conditions	Anchor Bluff	Point Point	East Spit	Mud Bay	Bear Cove	Mallard Bay	Glacier Spit	Peterson China Poot	Tutka	Total
4 30	good			0	177	0	0	0	0		177
5 1	good				76	5	0	0	0	0	82
5 3	good				12	0	0	0	0		12
5 6	good				0	0	0	0	0		0
5 12	good			0	169	0	39	0	0		208
5 15	fair			0	0	0	0	0	0		0
5 17	good			0	0	0	21	0	0		21
5 20	good			0	14	0	8	7	0	0	29
5 22	excellent		0	0	0	0	43	1			44
5 24	excellent			7	0	53	14	0	0	202	276
Total			0	7	447	58	124	9	0	202	848

Biomass Estimates in Tons

date	Survey Conditions	Anchor Bluff	Point Point	East Spit	Mud Bay	Bear Cove	Mallard Bay	Glacier Spit	Peterson China Poot	Tutka	Total
4 30	good			0	195	0	0	0	0		195
5 1	good				84	6	0	0	0	0	90
5 3	good				13	0	0	0	0		13
5 6	good				0	0	0	0	0		0
5 12	good			0	186	0	43	0	0		229
5 15	fair			0	0	0	0	0	0		0
5 17	good			0	0	0	23	0	0		23
5 20	good			0	15	0	9	8	0	0	32
5 22	excellent		0	0	0	0	47	2			49
5 24	excellent			8	0	58	15	0	0	223	304
Total			0	8	493	64	137	10	0	223	935

Table 7. Age, sex, and size composition of herring sac roe harvest using test fish sample data, Tonsina Bay, Outer District, 24 May 1991.

		Numbers of Fish						Percent	Weight			Length		
	Age	Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total	of Total	Mean (g)	SD	Number Weighed	Mean (mm)	SD	Number Measured
24 May	1													
	2													
	3	39	2	44	5	3	93	94.9	72	9.9	93	174	7.8	93
	4	0	0	3	0	0	3	3.1	115	10.6	3	199	6.0	3
	5	0	0	1	0	0	1	1.0	135	0.0	1	208	0.0	1
	6													
	7	0	0	0	1	0	1	1.0	156	0.0	1	231	0.0	1
	8													
	9													
	10													
	11													
	12													
	13													
	14													
	15													
	16													
Sample Total		39	2	48	6	3	98	100.0	74	16.1	98	176	10.9	98
Sex Composition		39.8	2.0	49.0	6.1									
Unaged		1	0	1	0	0	2	2.0	90	6.4	2	189	7.8	2
Sex Composition		50.0	.0	50.0	.0									

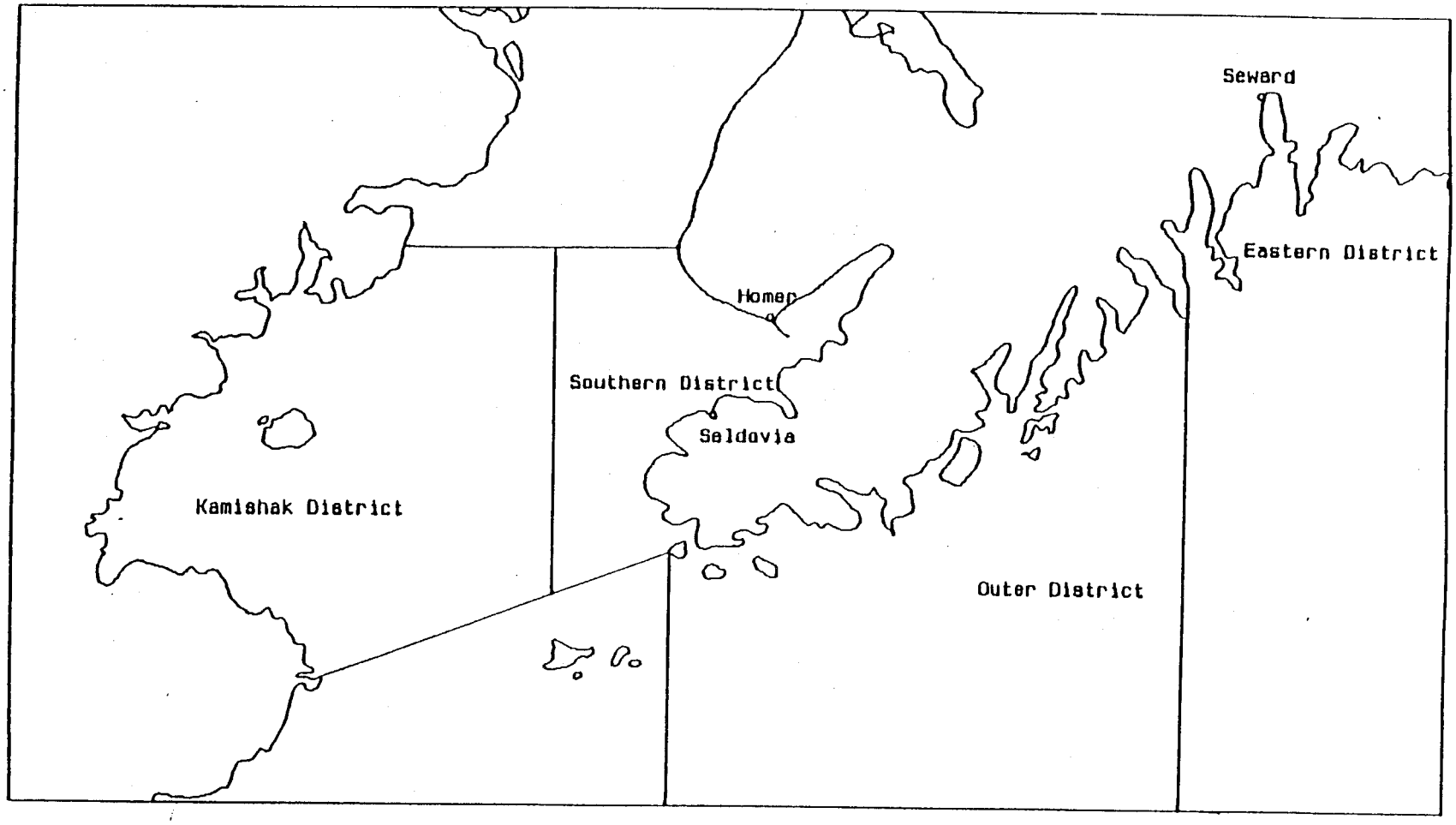

Figure 1. Kamishak Bay, Southern, Outer, and Eastern Districts of Lower Cook Inlet Management Area, Alaska.

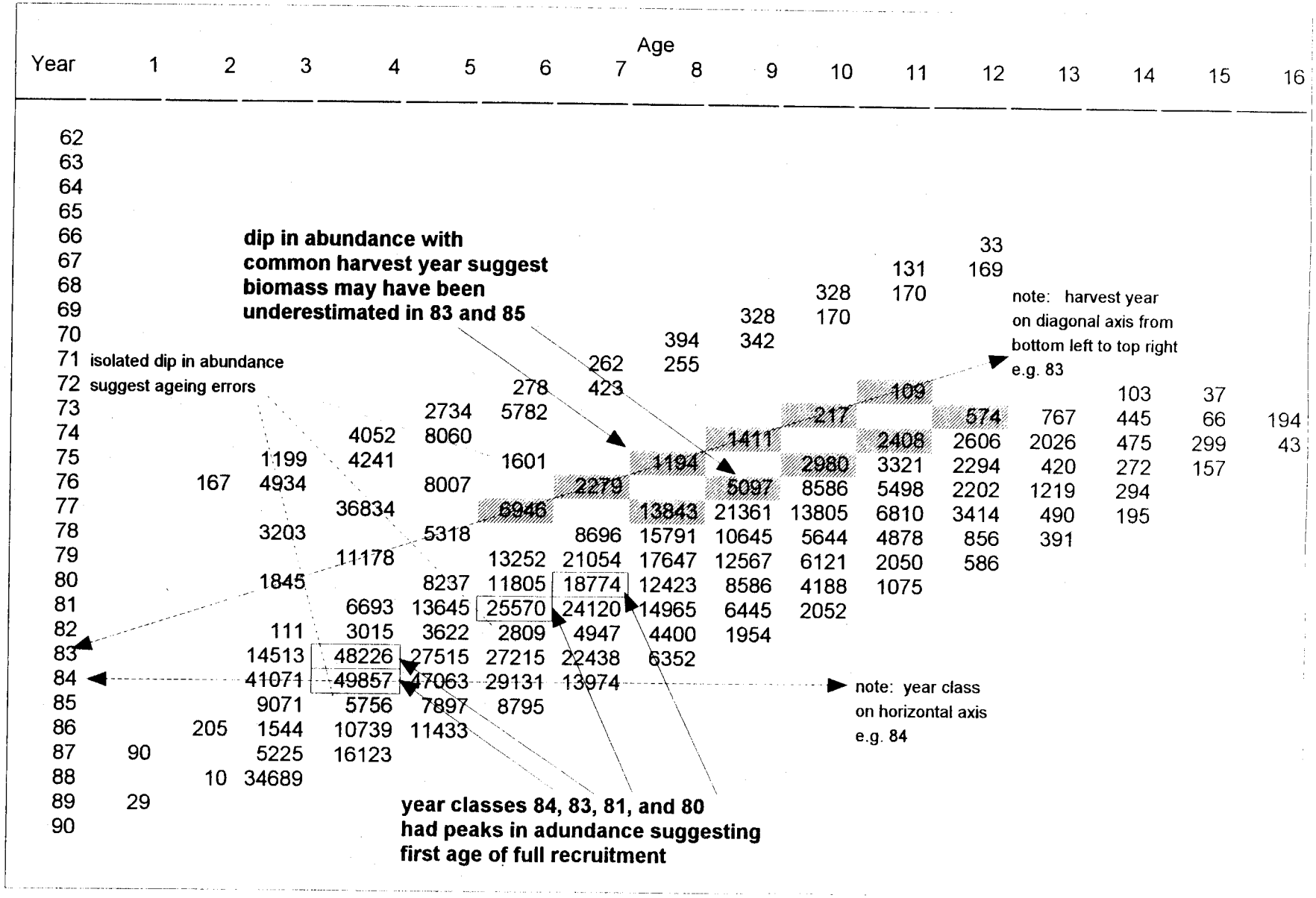

Figure 2. Kamishak Bay District herring abundance (x 1,000) by year class and age illustrating recruitment and decay over time

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
62																
63																
64																
65																
66																
67																
68																
69										0.2						
70									0.2							
71								−0.3								
72							−0.4									
73						−0.8								0.9		
74					−1.2								0.5			
75				−1.1								0.2	1.2	0.2	1.7	
76			−1.7								0.3	1.4	0.2	0.3		
77		−3.8								0.4	0.6	0.3	1.2			
78									0.4	0.4	0.4	1.7				
79							−0.7	0.3	0.4		1.5					
80						−0.6	0.1	0.1	0.5	0.9						
81					−0.4	−0.5	0.2	0.1	0.5							
82				−0.8	−0.7	−0.2	0.2	0.6								
83			−3.4	−0.3			−0.1									
84			−1.3		−0.2	0.0										
85			−0.3	−0.1	0.3											
86																
87		−2.0	−1.9													
88																
89																
90																

M+R can be calculated for this year class and age but was not used in the analysis.

Figure 3. Kamishak Bay District herring M+R by age and year class.

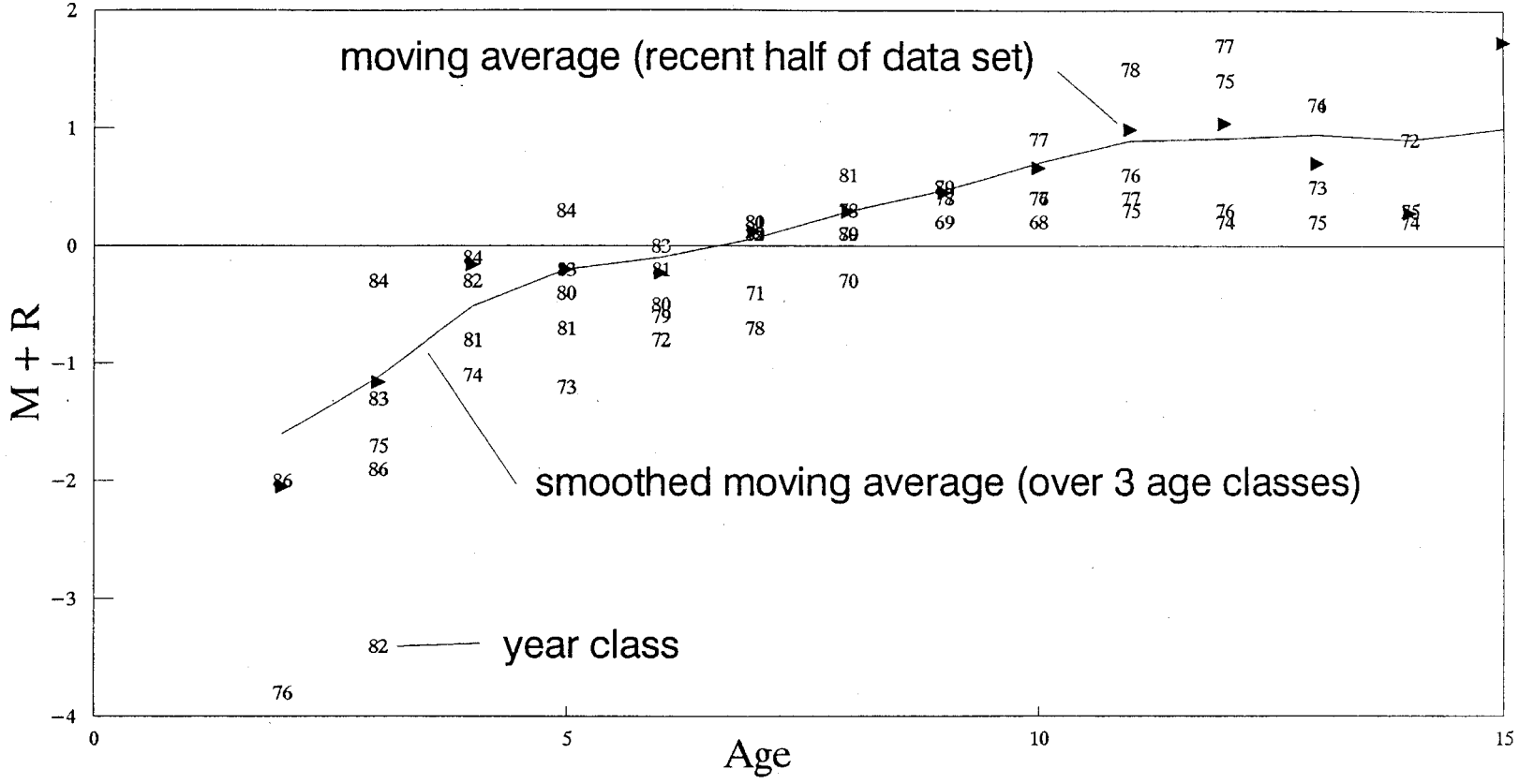

Figure 4. Kamishak Bay District herring M+R curve by year class.

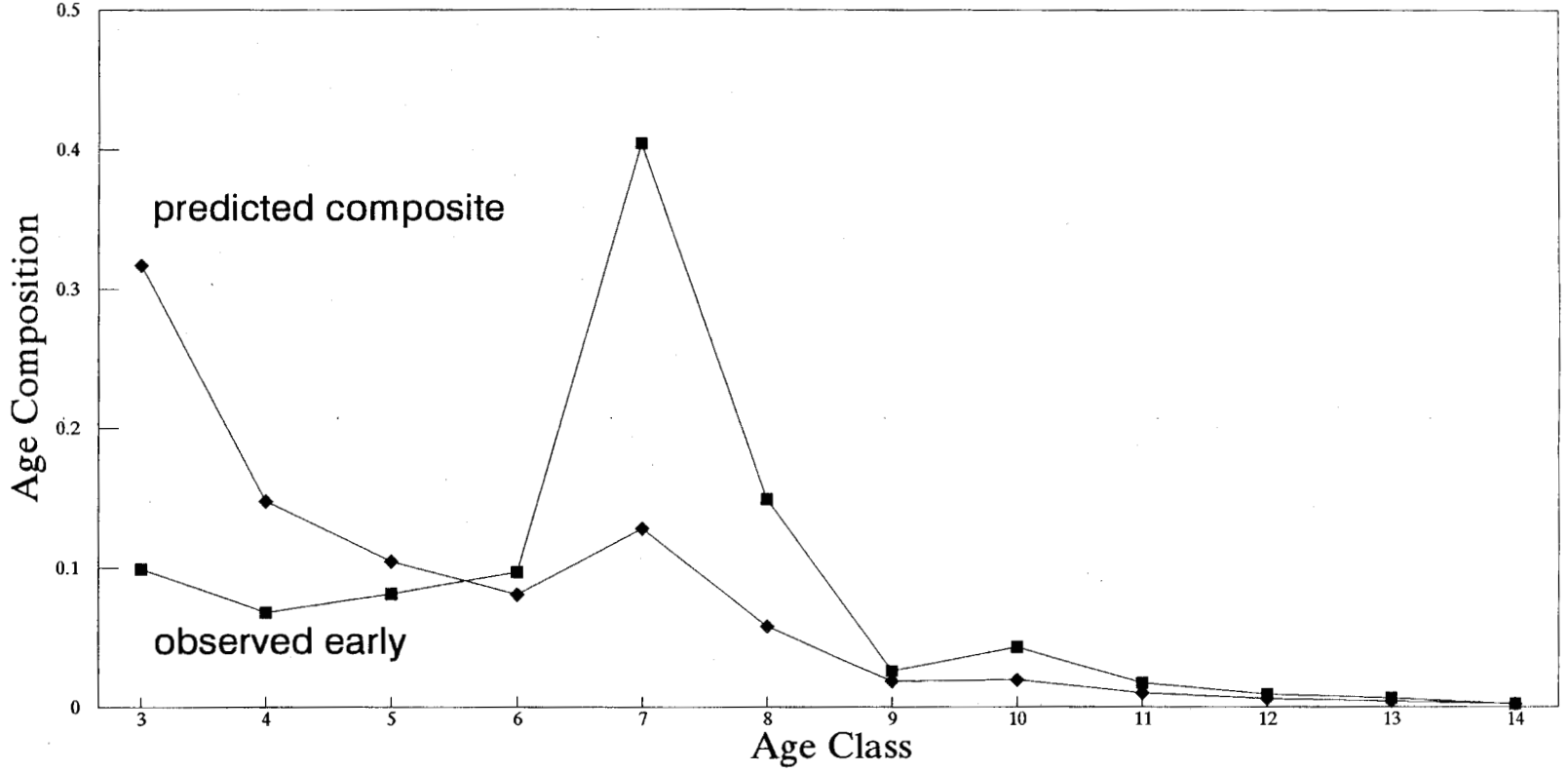

Figure 5. Observed early and predicted composite (early+late) Kamishak Bay District age composition.

APPENDIX

Appendix A. Kamishak Bay District herring age composition by year of harvest.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
78	.0	1.7	12.1	40.9	27.6	2.8	2.7	4.0	3.3	3.3	1.3	.3	.0	.0	.0	.0
79	.0	.0	20.1	17.3	32.9	23.5	1.7	1.0	1.4	.7	.7	.7	.0	.0	.0	.0
80	no samples this year															
81	.0	.0	6.5	74.2	16.1	3.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
82	no samples this year															
83	.0	.0	6.0	36.7	17.4	22.8	7.5	3.9	4.6	.7	.4	.0	.0	.0	.0	.0
84	no samples this year															
85	.0	.0	.2	10.8	13.3	21.4	14.1	22.4	8.2	4.8	3.9	.9	.0	.0	.0	.0
86	.0	.0	12.4	2.6	11.7	10.2	18.1	13.6	18.4	7.4	2.8	2.2	.7	.1	.0	.0
87	.0	.0	23.7	27.7	1.9	12.5	9.3	8.6	5.0	6.5	2.6	1.1	1.0	.2	.0	.0
88	.0	.2	7.0	34.4	17.2	1.7	14.7	7.6	7.6	3.4	4.1	1.3	.3	.3	.0	.0
89	.0	.0	1.5	5.1	37.4	21.4	3.9	11.5	6.6	4.7	3.7	2.6	.9	.2	.2	.1
90	.0	.0	6.0	12.3	8.6	29.4	23.8	4.4	6.7	4.4	2.2	.9	.5	.3	.2	.0
91	.0	.0	9.9	6.8	8.1	9.7	40.4	14.9	2.6	4.3	1.7	.9	.6	.2	.0	.0

Appendix B. Kamishak Bay District herring mean weight (g) by year class and age.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
62																
63																
64																
65																
66												247				
67											212	265				
68										217	272					
69									204	221						
70								188	210							
71							170	197								
72						168	170				253			295	287	
73					121	156				218		275	292	288	282	296
74				85	128				210		255	281	288	262	313	299
75			61	98		121		196		248	272	275	298	293	275	
76		16	68		124		182		238	261	275	280	298	307		
77				88		160		220	249	264	266	288	286	313		
78			70		137		205	233	248	261	285	264	322			
79				118		182	215	235	248	268	266	307				
80			74		155	189	211	236	254	256	293					
81				125	155	193	217	245	249	281						
82			64	104	154	194	228	233	267							
83			88	122	159	199	209	259								
84			79	113	158	180	212									
85			77	131	160	201										
86		14	98	130	171											
87			82	119												
88		17	78													
89	4															
90	4															

Appendix C. Kamishak Bay District herring mean length (mm) by year class and age.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
62																
63																
64																
65																
66												252				
67											248	268				
68										252	274					
69									247	254						
70								243	258							
71							235	255								
72						235	246				291			262	256	
73					212	237				255		253	259	256	266	265
74				191	224				251		255	259	259	263	263	267
75			172	208		210		244		252	256	255	263	267	269	
76		120	186		214		241		248	254	254	262	265	274		
77				190		233		242	250	250	258	266	269	269		
78			180		223		237	247	246	257	266	266	271			
79				214		230	241	244	254	260	265	269				
80			191		220	233	237	251	259	259	266					
81				208	220	231	246	256	259	261						
82			173	197	218	239	251	255	261							
83			185	202	226	242	245	255								
84			177	204	225	234	240									
85			180	214	226	239										
86		108	191	212	229											
87			186	207												
88		117	182													
89	70															
90	70															